Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Department of Wildlife, Fish, and Environmental Studies

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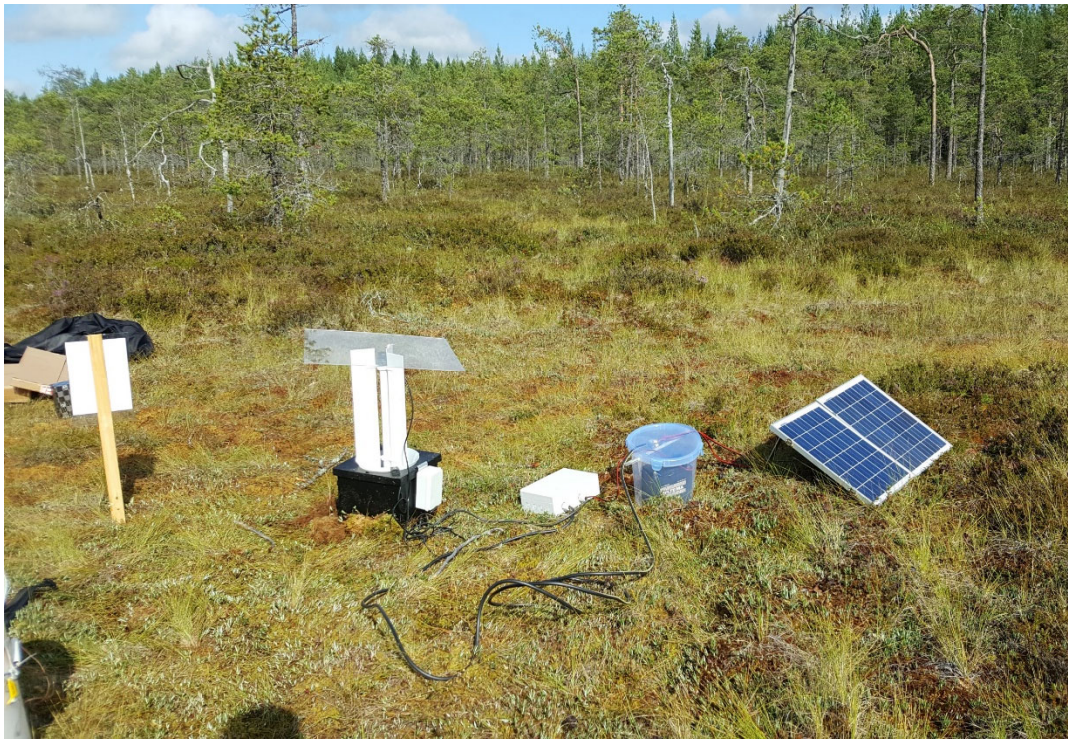

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Nocturnal moths use of novel habitats – A case study on a power line in a forest-mire mosaic in boreal Sweden

Oskar Lövbom

Supervisor: Anne-Maarit Hekkala, Swedish University of Agricultural Sciences, Department of Wildlife, Fish, and Environmental Studies

Assistant supervisor: Magnus Magnusson, Swedish University of Agricultural Sciences, Department of Wildlife, Fish, and Environmental Studies

Assistant supervisor: Jörgen Sjögren, Swedish University of Agricultural Sciences, Department of Wildlife, Fish, and Environmental Studies

Examiner: Joakim Hjältén, Swedish University of Agricultural Sciences, Department of Wildlife, Fish, and Environmental Studies

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Swedish University of Agricultural Sciences
Faculty of Forest Sciences
Department of Wildlife, Fish, and Environmental Studies

Abstract

Biodiversity and pollinators are declining all over the world, and a factor thought to cause this decline is destruction of natural habitats. One new way that has been discussed in an effort to try to mitigate the effects of declining habitats is to understand and use novel habitats, which are habitats created when, for example, building roads, railways, and power lines. This study aims to investigate if a novel bog habitat created by a narrow power line corridor in northern Sweden have another abundance, species richness or the assemblage structure of nocturnal moths than two natural bog habitats. I also analyse if environmental factor such as vegetation type and tree stand structure are different in the power line and try to link which environmental factors can be correlated to the assemblage structure of nocturnal moths. This was done by monitoring nocturnal moths for 38 days using bait traps and light traps in a nature reserve outside of Umeå. The traps were set in three different types of bog habitats (novel power lines, sparse bog, and dense bog) within a boreal forest-mire mosaic. Generalised linear models (GLM) were used to analyse abundance and species richness of nocturnal moths. Simpsons diversity index and Shannon-wiener index were used for analysing the alpha diversity and a non-metric multidimensional scaling (NMDS) were used to illustrate the assemblage structure in the habitats. The results showed no significant difference between the two different natural bog habitats and the novel power line for neither abundance, species richness, species diversity nor assemblage structure. Further, the results showed that the environmental factors of deciduous dwarf shrubs and vegetation diversity correlated with assemblage structure of nocturnal moths but could not be linked towards a specific habitat. Dwarf shrubs and deciduous trees was the two substrates mostly used as host plants and could be important structures for nocturnal moths in a forest-mire mosaic environment. However, due to the low sample size, the results should be interpreted with caution, but my results indicate that the novel open bog habitats created by power lines function as habitats for nocturnal moths equally as natural bog habitats with partially closed and closed tree canopy.

Keywords: pollinators, Lepidoptera, moth, transmission line, bogs, assemblage structure, Noctuoidea, Geometridae

Sammanfattning/Abstract

Forskare har under de senaste decennierna visat att den biologiska mångfalden minskar och att artutdöenden sker globalt. Dessa problem är oftast kopplade till mänsklig aktivitet och särskilt till följd av biotopförstörelse. Ett nytt sätt att få denna minskning av rimliga habitat att sluta kan vara att optimera användningen av så kallade ”nya biotoper”, såsom järnvägar, vägkanter och kraftledningsgator. I denna studie undersöker vi om de nya habitaten som bildas av en smal kraftledningsgata i norra Sverige har en effekt på nattfjärilar och deras förekomst, artrikedom och artstruktur i området. Studien gjordes med hjälp av betes- och ljusfällor i 38 dagar i ett naturreservat utanför Umeå, Västerbotten. Fällorna sattes ut i tre olika biotoper, två typer av trädbevuxna myrar och en kraftledningsgata. All data som samlades in analyserades i R, där två Generalised linear models (GLM) användes för att analysera antal individer och artrikedom. Simpson- och Shannon-Wiener diversitetsindex användes för att undersöka alfa-diversitet för områdena och Jaccards likhetsindex användes för att undersöka betadiversitet. Sedan användes två non-metric multidimensional scaling (NMDS) för att analysera artstrukturen både för habitaten och för nattfjärilarna. Resultaten visade ingen signifikant skillnad för nattfjärilarna mellan de olika habitaten i antal individer, artrikedom eller artstruktur. De flesta arterna som fångades var knutna till lövträd och kan ge en indikation att det är en viktig faktor för fjärilsfaunan samt så kunde vi se att buskskiktet och vegetationens diversitet korrelerade med nattfjärilsstrukturen men inte mot en specifik biotop vilket också troligtvis är viktiga faktorer för nattfjärilar. Det låga antalet fångade fjärilar gör att resultaten bör tolkas med försiktighet, men skulle kunna ge en indikation på att de nya biotoperna som bildas av kraftledningsgator inte påverkar nattfjärilar påtagligt utan kan fungera som biotop liknande de naturliga myrarna.

Nyckelord: pollinatörer, nattfjärilar, malar, kraftledningsgator, lepidoptera, störda miljöer, Noctuoidea, Geometridae

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1 Introduction

The decline of biodiversity and pollinators has for the past years been well documented (Biesmeijer et al. 2006; Newbold et al. 2015). Where several studies have shown the decline have been happening over a long period of time (Hallmann et al. 2017; Klink et al. 2020), while other studies have found a number of factors thought to be linked to the decline (Exeler et al. 2009; Frankie and Thorp 2009; Garibaldi 2009; Goulson et al. 2015; Roszko et al. 2016; Schowalter 2016). One of these factors that that is thought to play a major role is the loss of natural habitats (May 2010; Mooney 2010). Habitats and environments are decreasing or changing due to how we humans manage the landscape, where changes in management methods and an intensification of land use have had a negative impact on biodiversity (Nilsson, Franzen and Jönsson 2008). In Sweden, boreal forests is one of the most affected landscape types, where the alternation of forests has affected the ecosystem with decreasing forest diversity and draining mire and bog areal (Essen et al. 1997; Ericsson, Östlund and Axelsson 1998; Gustavsen et al. 1998). Since, the mosaic of forests and wetlands have been identified as an important aspect for biodiversity in Swedish forests (Swedish Environmental Protection Agency 2005), understanding how changes in these areas affect the biodiversity is fundamental to understanding how to optimize conservation methods and minimize this decline.

One aspect to halt the decline of biodiversity and pollinators might be understanding how to optimize the use and the establishment of so-called novel habitats and how different species can use novel habitats as living space (Connell 2000; Hobbs 2006). Novel habitats are man-made areas that recently been created from disturbances. These disturbances change the biotic and abiotic factors of the habitat and creates new structures in the habitat (Hobbs et al. 2006; Skórka et al. 2018). However, these changes can instead make novel habitats resemble other habitats more than the original ones and could from this function as habitats for numerous new species (Angold et al. 2006; Hobbs et al. 2006). A better understanding of how these novel habitats are used by for example plants and pollinators could yield useful

information for conservation biology (Wojcik and Buchmann 2012). Novel habitats generally occur along industrial or infrastructure development, for example road verges or railways (Saarinen et al. 2005; Moroń et al. 2014). One other such man-made novel habitat is power line corridors and only in Sweden there are approximately 15 000 km (or 300 000 ha) of power lines creating open areas that could possible act as potential habitats for many species of pollinators (Grusell and Miliander 2004; Berg et al. 2016; Svensk kraftnät n.d.).

Many earlier studies have focused on the negative impact power lines can have on the environment, for example, fragmenting habitats by creating gaps, filtering animal movement (Vistnes et al. 2004), affecting forest bird mortality due to collisions with wires (Bevanger and Brøseth 2004) and exposing birds to electromagnetic fields (Fernie et al. 2000). However, the disturbances when creating and maintaining a power line also creates new areas that could function as living space for a large number of species (Johnson, Schreiber and Burgers 1979; Litvaitis 2001) This is due to the ecological structures that are created when establishing and maintaining a power line, where the continuous disturbance creates open areas where early succession environments are favoured (Wojcik and Buchmann 2012). With less trees and less canopy cover, the area under the power line gets more sun, which leads to plant species such as forbs and graminoids to colonize an area and creating higher abundance of flowers and pollen, hence favouring e.g. pollinators (Van Geert et al. 2009).

Earlier research has shown that power lines can work as suitable habitats for grassland butterflies (Ahrné et al. 2011; Lampinen et al. 2018) and wild bees (Russel et al. 2005). Mainly since the abundance of flowers as food/pollen source and the possibility to nest or find host plants increases (Russel et al. 2005). However, few studies have investigated the effects power lines can have in other environments, such as wetlands, where pollinators also been shown to decrease (van Swaay, Warren and Lois 2006) and even fewer studies focusing on nocturnal moths. Understanding how all pollinators are affected in all habitats, especially those which has been identified as important for biodiversity, e.g. boreal forest-mire mosaics, is important (Swedish Environmental Protection Agency 2005). More studies in boreal forests and mire environments would thus give a better knowledge about how these linear novel structures works. In addition, linear structures (such as power lines) and corridors have been identified as important dispersal corridors for some diurnal butterflies (Van Geert et al. 2010; Modin 2018) and nocturnal moths (Mönkkönen and Mutanen 2003). This might be important for conservation purposes as migration through power lines can increase the connectivity between habitats and allows lepidoptera species to move more easily between habitats.

When monitoring the decline of pollinators, nocturnal lepidoptera species is often overlooked (Devoto et al. 2011) and even though they represent approximately 90% of the Lepidoptera family, a majority of studies focus on their diurnal relatives (Shields 1989). The reason for this selection is probably due to a lower interest from the general public about nocturnal moths than for diurnal moths and butterflies and that nocturnal moths fly for the majority of time during the nights (New 2004). However, nocturnal moths have as many other groups of pollinators been found to decrease in abundance (Fox 2012), and this decline could in turn affect other parts of the ecosystem. Since, nocturnal moths play a vital role in the ecosystem as pollinators (Walton et al. 2020), e.g. for pollination of Caryophyllaceae and Orchidaceae (Hahn and Brühl 2016), and in addition nocturnal moths are also herbivores and function as bulk food for birds and bats (Fox 2012). Furthermore, nocturnal moths have shown a fast response to changes in both the micro and macro environment, disappearing if not the right vegetation structure or plant species occurs in an area. The group could therefore be a value for understanding and for assessing ecologic values and could help with knowledge how to conserve biodiversity (New 1997; De Smedt et al. 2019), strengthening the importance to understand how nocturnal moths is affected by human activity and the novel habitats we create.

Since a majority of previous research focus only on corridor and power lines affects diurnal butterflies and moths a need for further studies investigating the effects on nocturnal moths are needed. Therefore, I will study how a power line corridor in a nature reserve in northern Sweden affects nocturnal moths. By using bait- and light traps I investigate if (1) the power line affects the abundance and species richness of nocturnal moths. I will also (2) analyse if there is a difference in assemblage structure of nocturnal moths within power lines and natural bogs and (3) assess which environmental factors correlates with the occurrence of nocturnal moths in the environments. From the earlier literature stated in the introduction we can see that power lines in general have had no negative effects on pollinators, due to this I expect to find:

1. That there will be no difference in abundance or species richness of nocturnal moths between the three habitats.
2. The assembly structure in the power line habitat will have not be significant different from the other two bog habitats. However, I think it will include more species of other habitats since the vegetation structure in the power line corridor is expected to change.
3. Species occurrence of moths will be correlated with what plant species and structures we find in the area since most lepidoptera species follow the occurrence of their host plants.

2 Method

2.1 Study area

This study took place in Grössjön nature reserve in northern Sweden, approximately 6 km from Umeå centrum (Fig. 1 C), between August 11th and September 20th in 2019. Grössjön was established as a nature reserve in 1996 and is known for its' recreation areas, its' lake, and its' forest-mire mosaic environment. The forests in the reserve is characterised by bilberry (V. myrtillus) type spruce forest of varied age, with stands to over 120 years. The reserve has almost as large of an area with mires and bogs as forest. The bogs (defined by me as a type of mire with trees growing in them) are dominated by Sphagnum-species (Umeå Kommun 1997) with a mix stand of birch, pine, and spruce. In the northern part of Grössjon nature reserve a power line crosses through the forest and wetlands and were chosen as study location (Fig. 1). The power line creates a corridor of 10-15 meters width, which can change the composition of plants and structure of the forest-mire mosaic, creating a so-called novel habitat. This novel habitat is maintained by clearing the power line of understory trees and trees close to the power line every 8-12 year (Svensk kraftnät n.d.). This makes the power line corridor characterised by more sun light, less trees and through the maintenance creating additional ground disturbance which all creates a more open area. Along the power line, four locations in separate bog areas were chosen (Fig. 1 A). In each location, a transect of 100 meters running in north-south direction through three different habitats (Dense bog, Power line and Sparse bog). In each transect, three traps for nocturnal moths was placed, one in the middle of the power line and one on each side of the power line approximately 50 meters

from its centre. The different sides of the power line were categorized as either sparse or dense bog depending on their basal area (Fig. 1 B).

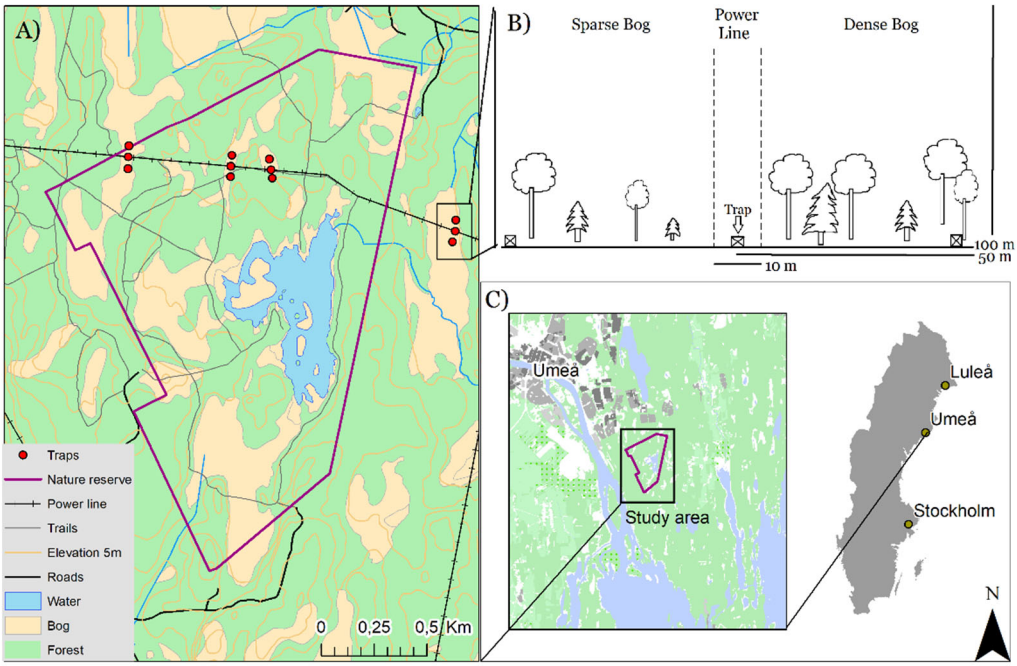

Figure 1. A) Map over Grössjöns nature reserve with trap locations. B) Study set-up for three traps C) Grössjöns nature reserve location in Sweden.

2.2 Study organism

Nocturnal lepidoptera, casually called moths, includes all Lepidoptera that have a nocturnal way of living, hence excluding day active butterflies and moths. Nocturnal moths are a large group which incorporates around 90% of the worlds known lepidoptera species (Shield 1989) and the group can be found in a vast choice of habitats. In Sweden, a total of 2825 lepidoptera species have been described, of which around 2690 are nocturnal moths (Artdatabanken n.d.). Nocturnal moths can be further divided into two groups: macro- and micro-lepidoptera. In this study I chose to focus on macro-lepidopteras, henceforth referred to as nocturnal moths. In Sweden, macro-lepidopteras can be divided into two larger groups: superfamily Noctuoidea and the family Geometridae, containing approximately 640 and 332 species respectively (Artdatabanken n.d.). In Västerbotten, where my study took place, a combine count of 250 species have been reported in September and October of the two groups (Artportalen n.d.). The two groups were chosen since they are a large group of lep-

idoptera species that is fairly easy to identify and could harbour unknown information for understanding of how ecosystems work. For example, families included in Noctuoidea, e.g. such as Sphingidae and Notodontinae, have been found to be good tools when evaluate environmental conditions, biodiversity and abundance of moths in forests in North America (Summerville, Ritter and Crist 2004; Kitching et al. 2013).

2.3 Bait and Light traps

During the study period two types of traps were used (described below). For each trap location first a bait trap was placed for eight nights (between 11-19th of August) and after that the bait trap was substituted for a light trap that was out for 30 nights (between 21st of August and 20th of September). The traps were placed on the ground in four transects and were checked every second day, except for one period, August 31st to the fourth of September, when I was sick and unable to collect the moths from the traps.

The bait traps that were used followed the "Oulu"-model and was constructed using a 20 litres buckets with a lid (Laaksonen et al. 2006) (Fig. 2). From the lid hung a bait, which consisted of a sponge soaked in a solution of wine and sugar, mixed according to earlier studies of four litres of wine and two kg of sugar (Yela and Holyoak 1997; Pettersson and Franzén 2008). In the side of the bucket three holes were made and equipped with a plastic sheet creating entrance tubes, letting moths in but making it harder for them to get out again (Fig. 2). Inside the bucket another funnel was placed, with the same function as the earlier ones, to make it easier for moths to get into the lower part of the trap but hard to get out. In the bottom of the bucket a cellular insole was placed to soak up water and help the moths keep dry. Inside the bucket a bottle of ethyl-acetate was placed to kill any moth and making it easier to collect them.

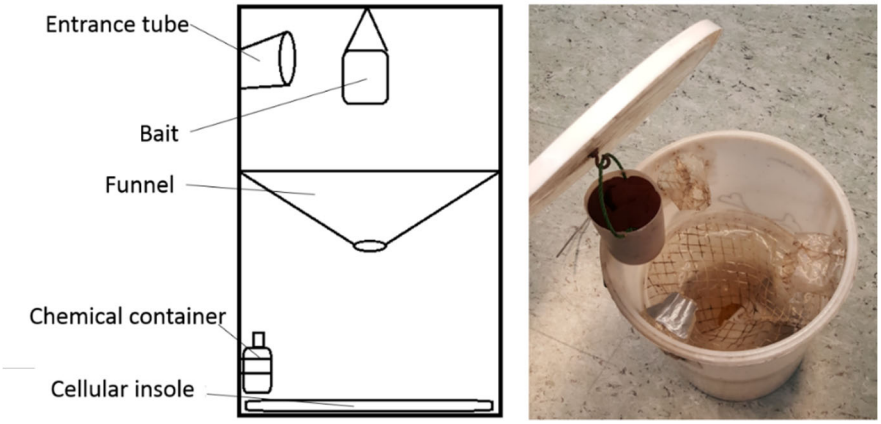

Figure 2. Bait traps of the "Oulu" model. Schematic picture (left) and a picture (right) of the traps used in this study

After eight nights the bait traps were assessed to be too inefficient and that the nights were dark and long enough, so the bait traps were replaced with light traps. One light trap was constructed using a plastic box with a funnel as a roof (Fig. 3). Above the funnel a lightbulb (368 nm wavelength and 15W) was placed between three plastic walls. The light bulb, powered by a car battery (12V, 20Ah), lures the nocturnal moths to fly into the walls which then fall into the box. Inside the box, egg cartons were placed making the moths settle down. All traps were active every night for a duration of four hours, between 22-02 since this seemed to be an optimal time from earlier studies (Environmental Data Centre 1994). During the days, the battery was charged using a solar panel connected to the battery (Fig. 3).

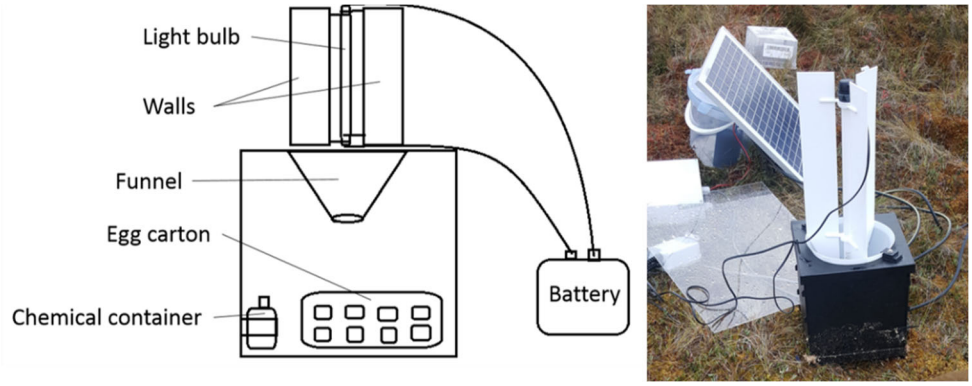

Figure 3. Schematic picture, excluding the solar cells, (left) and a picture (right) of light traps used during this study.

2.4 Sampling and identification

All macro moths from the superfamily Noctuoidea and from the family Geometridae were collected from the traps, frozen (to ensure the moths were killed and did not rot) and counted. Later all moths were pinned and identified to species or, in a few cases to genus or a wider taxonomic grouping. The moths were identified using "Sveriges fjärilar" (Elmqvist et al. 2019), and "Nordens Ugler" (Skou 1991), and from literature found online (vilkenart.se, lepitoptera.se, lepiforum.de). A few moths were impossible for me to identify and were sent to the Swedish museum of natural history, Stockholm, for professional help from an experienced researcher (Bert Gustafsson, emeritus Curator).

2.5 Environmental data

For each trap location, the following measurements were taken: the field and ground layer vegetation species and cover, tree canopy cover, understory trees and stand basal area. The basal area was measured in a circular area of 10 m radius around each trap. In this area all trees above 1.3 meters were identified to species and had their diameter at breast height (DBH) measured. Basal area could be calculated using:

$$A = \pi \left(\frac{DBH}{2}\right)^2$$

All trees with a DBH ≤30 mm was counted as "understory trees" and were not included when calculating basal area. The vegetation cover was inventoried in three 1x1 meter quadrats 2.5-meters from the trap. The first inventory square was placed along the power line towards west and the other two were placed in 120 degrees from the first. In each square all vegetation was identified to species, except for grasses and mosses which were identified to genus. For each species, the ground cover was estimated to the closest percentage. All identified species were grouped into functional groups (Evergreen dwarf shrubs, deciduous dwarf shrubs, forbs and graminoids, deciduous tree, coniferous tree, forest moss and swamp moss) according to Hekkala et al. (2014) to be used in a later analysis. To calculate the canopy cover, a picture was taken just above the trap in an upwards position using a mobile phone. The picture was later analysed by transporting it to a computer and then using the program ImageJ (Ferreira and Rasband 2012). In ImageJ the picture was converted to black and white and each cell could be counted, and from this a percentage of canopy cover could be obtained.

2.6 Data analysis

2.6.1 Environmental data

All data were analysed using R (Version 3.6.2; R Core Team 2019). When analysing the vegetation data, the percentage of each species cover from each subplot were converted to a mean percentage cover for the trap location. From this a Shannon-Wiener diversity index were calculated for each plot. To test the diversity for the different habitats further a Linear Model (LM) was used to test the Shannon-Wiener scores for a significant difference. To assess environmental differences between the power line and bog trap stations, canopy cover, understory trees and stand basal area were tested. The understory trees were calculated as counts and tested using a generalized linear model (GLM) using gaussian family (Dobson 1990). The basal area was tested using a LM and the same method was used for canopy cover, however canopy cover was first arcsin square root transformed to better fit the requirements of a linear model (Crawley 2013). A non-metric multidimensional scaling (NMDS) was preformed, using the vegan-package (Oksanen et al. 2018), to measure similarity in vegetation species composition between the different habitats. This technique determines the vegetation composition in each site by giving it a score. The site scores could then be group into habitats to see the overall species composition in the different environments and the standard deviation of the ordinations site scores for each habitat could be illustrated by an ellipsoid. Using the envfit-function environmental factors (Basal area, canopy cover, understory trees) could then be fitted over the NMDS site scores using 999 permutations. The function determines which factors correlate with the vegetation composition using the ordination scores and environmental variables. To only illustrate the statistically significant variables the p-value were set to 0.05. For assessing the difference between habitats within the NMDS an ADONIS tests were used. The ADONIS analyse the variance of distance and sum of squares using dissimilarities to check if there is a difference in the assemblages between the habitats (Anderson 2001).

2.6.2 Moths

Every moth was counted and identified, after that the moths from both trap types were pooled together, to form a season-long characterization for each trap location. A GLM (error family = Poisson) was used for analysing the differences in species richness and moth abundance between habitats. Species diversity were estimated for nocturnal moths in each of the locations and between the three different habitats,

using three different diversity indices. Shannon-Wiener diversity index and Simpson's diversity index were applied to compare the alpha diversity for each habitat (Lande 1996). Both indices are well used within ecology and are composed of species richness and evenness components. To compare the beta-diversity between the different habitats a Jaccard's similarity index was used. For further comparisons between the habitats the results from the Shannon-Wiener diversity index and Simpson's diversity index were tested with a linear model. To analyse the assemblage structure for the nocturnal moths the different traps were fitted in a NMDS. Since, the low number of individuals no further filtration to the data were made and the site scores were grouped accordingly to habitat with the standard deviation for the site scores for each habitat illustrated by an ellipsoid. The vegetation data, grouped according to Hekkala (2014), and the environmental structures could then be fitted over the moth assemble structure using the envfit-function, using 999 permutations. To gain a more thorough understanding of what could be more correlated with the nocturnal moth assemblage structure only the significant trends (p-values < 0.05) were fitted over the NMDS. Assessing the significant difference for nocturnal moths between the three habitats in the NMDS an ADONIS test was used.

3 Results

3.1 Nocturnal moths

After 38 nights of trapping, 82 nocturnal moths were caught and of these 76 could be identified into 28 different species (Appendix, table 4). One moth was identified to genus-level and the remaining unidentified were grouped into families, two into Geometridae and three into Noctuidae. In general, most of the species found occurred quite sparsely throughout the inventory and was often only found fewer than 5 times. With the exception of *Amphipyra perflua*, *Celaena haworthii* and *Eulithis populate* which were found ten, seven and seven times, respectively, and were the most abundant species in this study (Appendix, table 4).

3.2 Species richness and abundance of nocturnal moths

No significant difference could be found in abundance of the nocturnal moths between the sampled habitats (Fig. 4A, Table 1). Similarly, the species richness was not significantly different between the habitats (Table 1), however, there is a small trend towards Dense bog containing less species than the other two habitats (Fig. 4B). Neither when analysing the nocturnal moth diversities using Shannon-Wiener- or Simpson's diversity index could any difference be found between power lines and the two different bog habitats (Table 2). Further, the linear models showed no difference between habitats analysing Shannon-wiener or Simpson's diversity indices (Table 1). Examining the beta-diversity using Jaccards' similarity index showed a resemblance between habitats where Sparse bog and Power Line shared 48% of

the species found, Power Line and Dense bog shared 46% and Sparse bog and Dense bog shared 33%.

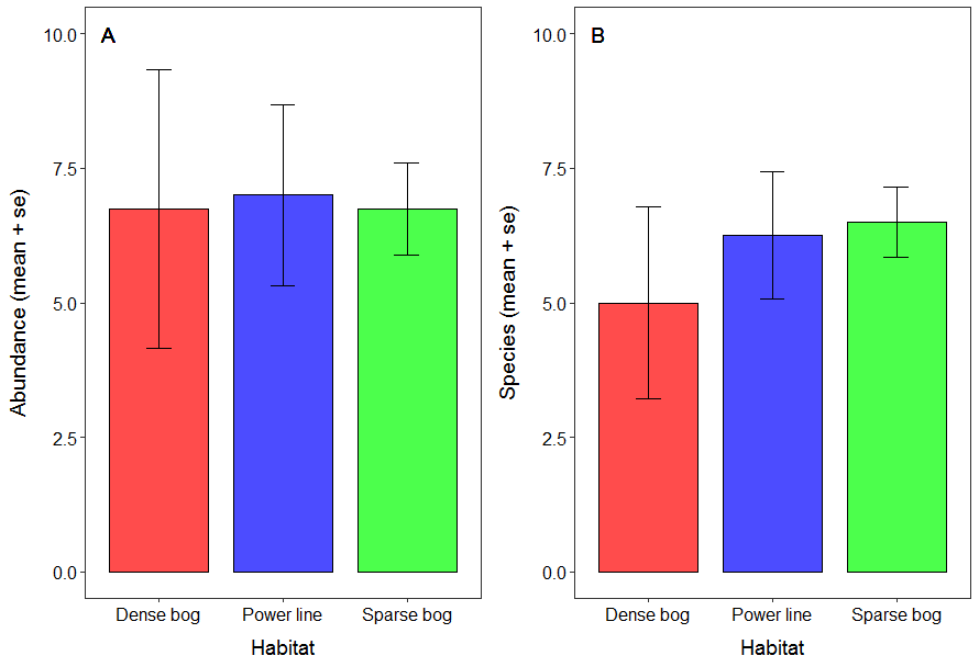

Figure 4. A): The mean count/abundance of nocturnal butterflies caught in the different habitats. B) The mean number of butterfly species found in each habitat.

Table 1. *Summary statistic tests, intercept set to Power lines. Type of test in brackets.*

Abundance (GLM)	**Estimate**	**Std.Error**	**z-value**	**p-value**
(Intercept)	1.9456	0.189	10.297	<2e-16
Sparse bog	-0.036	0.270	-0.135	0.893
Dense bog	-0.036	0.270	-0.135	0.893
Species richness (GLM)	**Estimate**	**Std.Error**	**z-value**	**p-value**
(Intercept)	1.833	0.200	9.163	<2e-16
Sparse bog	0.039	0.280	0.140	0.889
Dense bog	-0.128	0.292	-0.437	0.662
Shannon-wiener Diversity (LM)	**Estimate**	**Std.Error**	**z-value**	**p-value**
(Intercept)	1.747	0.243	7.186	5.16e-05
Sparse bog	0.100	0.344	0.291	0.777
Dense bog	-0.290	0.344	-0.842	0.421

Simpsons Diversity (LM)	Estimate	Std.Error	z-value	p-value
(Intercept)	0.986	0.015	64.461	2.63e-13
Sparse bog	0.007	0.216	0.309	0.764
Dense bog	-0.021	0.022	-0.989	0.348

Table 2. *Species diversity for nocturnal moths with Simpsons (D) and Shannon-wiener (H') diversity index for nocturnal moths*

Habitat	Moth diversity (D)	Moth diversity (H')
Sparse Bog	0.99(±0.01)	1.85(±0.10)
Power Line	0.97 (±0.01)	1.75(±0.23)
Dense Bog	0.95 (±0.02)	1.46 (±0.34)

3.3 Nocturnal moth assemblage structure

The moth communities overlap rather considerably between the three habitats (Fig. 5) and testing the NMDS for nocturnal moths showed no significant differences between habitats (Adonis, F-value = 0.341, p-value = 0.988). Vegetation diversity (H')(r2 = 0.50, p-value = 0.03) and the occurrence of deciduous dwarf shrubs (r2 = 0.59, p-value = 0.014) correlated with the nocturnal moth assemblage structure but not towards a specific habitat (Fig. 5).

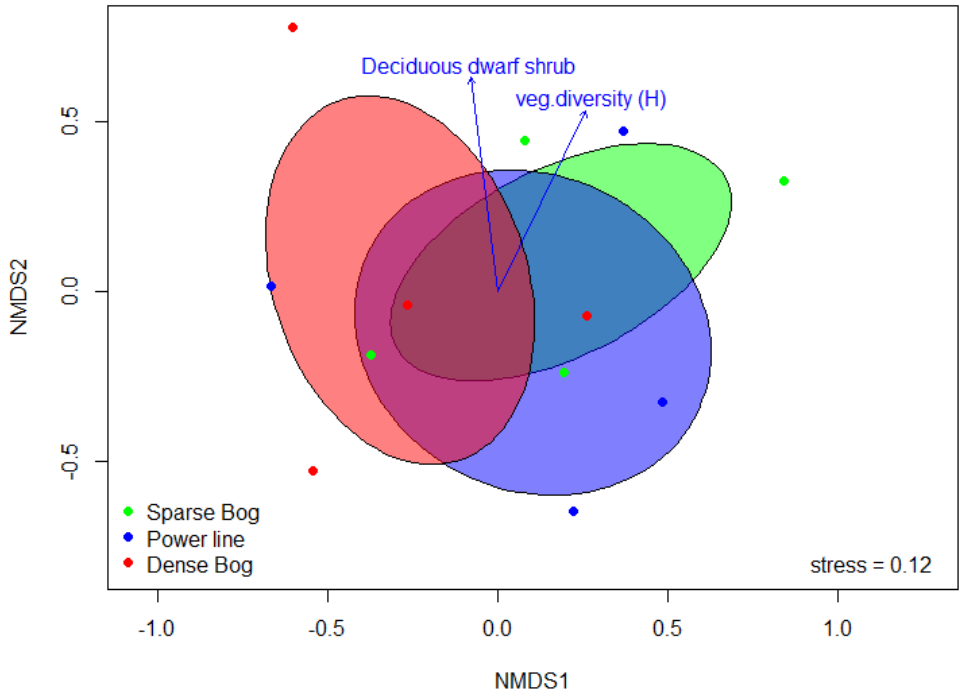

Figure 5. NMDS ordination showing nocturnal moth assemblage structure in the different habitats, with environmental factors correlating with the assemblage structure of nocturnal moths shown in arrows ($p < 0.05$).

3.4 Host plant preferences

In overall there were five species of nocturnal moths that could be directly linked to wetland and bog areas. The rest use forest environments (14 species) and general open areas (eight species) as habitats (Appendix, table 4). 71% of all species used deciduous trees as host plants, most common was Betula, Salix and Populus (Fig. 6), which can be found in all three of my habitats. The second most used substrate, with 46%, was dwarf shrubs, most common was Vaccinium and Calluna (Fig. 6).

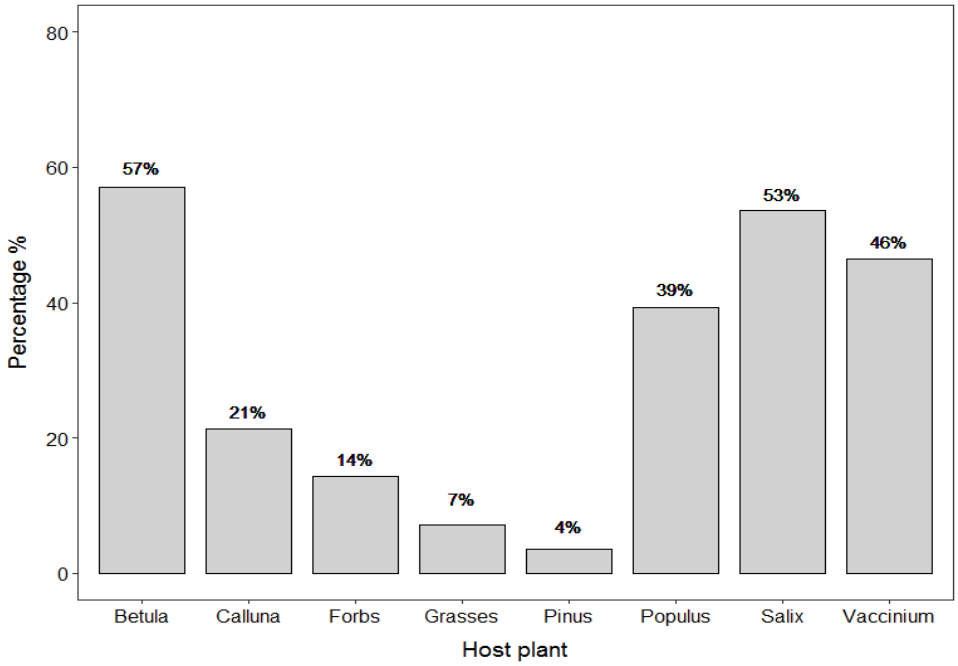

Figure 6. Most commonly used host family/genus amongst the caught nocturnal moths. Since most moths use multiple plants as their host plant the combined percentage can exceed 100%.

3.5 Vegetation and tree stand structure

The inventories showed that dense bog areas had higher stand basal area than sparse bog and power lines (Table 3), and that Sparse bog had higher count of understory trees than novel power lines. Even though no significant difference could be found there was a trend for lower canopy cover in power lines than the other two habitats. When analysing diversity, the Shannon-diversity index showed no significant difference. But the most common vascular plant species found were *Rubus chamaemorus*, *Vaccinium oxycoccos* and *Eriophorum vaginatum*, which were found at all locations. The species with the highest ground cover was *Calluna vulgaris*, however *C. vulgaris* could only be found at half of the locations. The power line habitats were in general dominated by swamp-mosses (92% coverage on average) which both of the bog habitats also were but with slightly less cover (Sparse bog = 74% and Dense bog = 66%). All plots had more swamp mosses than forest mosses, however the two natural bog habitats had on average a higher cover from of forest mosses (Sparse bog = 19.7%, Dense bog = 25.5%, Power line = 5.8%). Looking at vascular plants, the bog habitats had the highest cover by evergreen dwarf shrubs (Sparse bog = 21%, Dense bog = 31%), where Power lines only had (11%) and instead had most area covered by forbs and graminoids (13.8%).

Table 3. *Mean (± se.) values of the environmental variables in the different habitats. Lower case letters represent the statistical differences between the habitats, different letters show statistical difference between habitats (p<0.05).*

Habitat	Basal Area (m2/ha)	Understory Trees (count)	Canopy Cover (%)	Vegetation Diversity (H')
Sparse Bog	3.18 (±0.3)^{a}	33 (±9)^{b}	8.9 (±3.71)^{a}	1.72 (±0.09)^{a}
Power Line	1.78 (±1.10)^{a}	9.5 (±3.3)^{a}	0.6 (±0.10)^{a}	1.56 (±0.10)^{a}
Dense Bog	11.29 (±3.88)^{b}	19 (2.4)^{ab}	19.1 (±2.29)^{a}	1.38 (±0.25)^{a}

3.6 Vegetation composition

NMDS ordination for the vegetation communities show a trend for power line habitats to differ from the two bog habitats. However, there were no significant differences in vegetation composition between the bogs and power line (Adonis, F-value = 0.805, p-value = 0.509). Basal area (r2 = 0.66, p-value = 0.008) and canopy cover (r2 = 0.77, p-value = 0.001) had a significant correlation with the vegetation communities, both increasing towards dense bogs (Fig. 7).

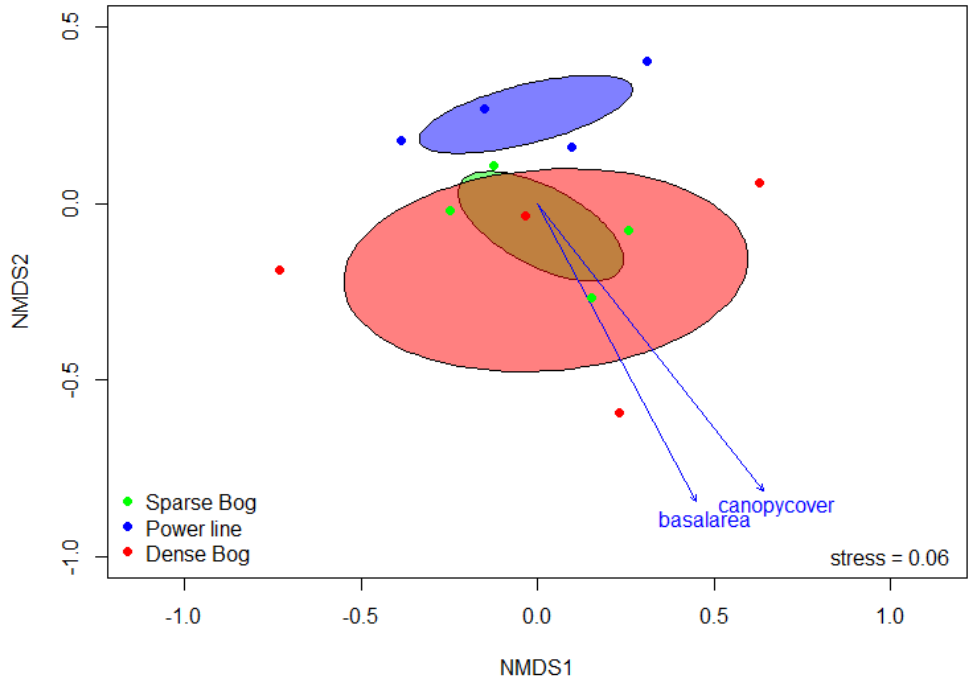

Figure 7. NMDS ordination displaying similarities for vegetation composition between the three habitats. Arrows showing linear correlation between environmental data and plant composition (p < 0.05).

4 Discussion

This study is one of the first trying to quantify the abundance, species diversity and assemblage structure of nocturnal moths in novel linear structures in a boreal environment. No significant differences in individual abundance, species richness, diversity or species assemblage could be found trying to differentiate the three habitats, indicating that the novel open habitats created by power lines might function equally good as habitats for nocturnal moths as natural bogs with partially closed and closed tree canopy. This could also imply that power lines might be able to help mitigate of the negative affects human activity have had on mire and bog environments. However, due to the low number of nocturnal moths caught during this study, the results should be interpreted with caution and it is important with further studies to provide sufficient evidence for any mitigation effects.

4.1 Abundance and Species richness

Analyses of the abundance and species richness of the nocturnal moths showed no difference between the habitats, confirming my first hypothesis. One explanation to this might be that there is simply no difference between the novel habitats created by the power line or the natural bog habitats in how they would function as habitats for nocturnal moths living in or closed to bogs. This would be in line with other findings of diurnal butterflies found in mire structures. In a study by Lensu et al. (2012), the abundance of diurnal butterflies showed no significant difference between mires in power lines and natural mires. They argue that as long as the environment and microclimate is similar between the habitats created by power lines and the natural mires, they can show the same tendencies to function as habitats for moths. As seen in my vegetation analysis this could be true. The novel habitats are still similar to the natural bogs in vegetation and stand structure and might due to this does not yield a larger or smaller abundance or species richness of nocturnal

moths. Another explanation to the results showing the habitats being similar, could be that the power lines affect the bog habitats, eliminating any differences the power line could create. Earlier studies focusing on diurnal butterflies showed that larger power lines (up to 120 meters) could have effects up to 500 meters from the corridor (Berg et al. 2016). Increasing the distance from the power line would allow us to better see if there is a response to the novel habitats created. Since this was only a small-scale case study a response from nocturnal moths might be hard to show. However, nocturnal moths have been shown to be affected by a change in vegetation (e.g. Lomov et al. 2006) and the power line only showed small differences compared to the two control habitats in some of the structural elements and no difference in vegetation diversity (Table 3; Figure 7). It is more likely that the narrow power line and surrounding bogs are equally good habitats for nocturnal moths. This would also follow ideas from Intachat et al. (1997) and Summerville and Crist (2002), which argues that as long as abiotic or biotic functions and original structures remains, the area would still work as habitats for nocturnal moths.

With continuous disturbance from management methods such as cutting down trees and clearing the power line, the novel habitats will continue to stay open which might create a more heterogeneous environment in the power line compared to natural bogs. Because of this the early successional phases in the novel power line may create another floral abundance and vegetation structure and in turn increase the possibility for power lines to function as habitats for other species of nocturnal moths (Intachat 1997; Highland et al. 2013). However, my results showed a trend for power lines, even though not losing abundance or species diversity of nocturnal moths, it became more covered by Sphagnum mosses and had a lower coverage from shrubs. This trend could indicate novel bog habitats in power lines to lose vegetation cover which could lead to a decrease in nocturnal moths (Highland et al. 2013). Although, the effect and how the bogs react to disturbance could also differ between different types of wetlands due to their locations and abiotic factors e.g. different types of bedrock.

An earlier study by Berg et al. (2016) used larger power line corridors where the size was up to 2-10 times larger than size of the power line used in this study and were able to find novel habitats to favour day living butterflies. Suggesting that my power line might be too small to affect the moth abundance and assemblage structure in the power line. Because, if power lines follow to the species-area relationship (MacArthur and Wilson 1967) where the larger the habitat area, the more species, and individuals it is capable to hold (Bergman and Landin 2001; Summerville and Crist 2001). Meaning that in power lines that becomes wider but where bog-vege-

tations structure does not change, bog living moths should be favoured from an increase in living area. However, if the power lines change the vegetation composition it could harm the bog living moth species. Instead, if lucky, switch the species composition to favour other lepidoptera species, for example grassland lepidoptera if the habitat becomes drier and dominant by grassland flower species.

4.2 Assemblage structure and vegetation composition

The nocturnal moth assemblages in the novel habitats had a high resemblance with the two natural bog environments, partly confirming my second hypothesis. However, no shift could be seen, the similarity in assembly structure could be caused by the reasons discussed earlier, such as the low difference in environmental factors between the three habitats. Which is also something seen in the vegetation species composition, showing no significance difference either between habitats, even though there seems to be a trend for power lines to change towards more open and moister habitat. Looking at the Jaccard's similarity index and the Simpsons diversity index, it showed around half of the moths we caught was unique for each habitat and that almost every moth caught were unique for the individual traps. This result could mean that there were quite many species living in the area, but the relative number of each species is low since most species were only caught once in each trap. The alternative is that moth abundance in bogs are generally low and the moths we caught were just passing through the habitats rather than living in them. If the low abundance is not an anomaly this could mean that nocturnal moths as a group might not be optimal to use when analysing nature values in bogs. However, I think that with more replicates, or longer sampling period, we would catch a larger number of moths. By also using broader power lines the novel habitats created in them would show a larger difference firstly for vegetation composition and thus possible also show how the moth assemblage structure would change with the environment in novel habitats. There might be a thing worth noticing though, studies from forests in North America suggest that nocturnal moths can have a high turn-over between similar habitats on a larger scale, which could make it harder to analyse species data in nocturnal moths (Summerville et al. 2001; Summerville and Crist 2008). To deal with such a problem, studies might need to be carried out for more than one season.

Distinguishing which environmental factors that correlated to the assemblage structure of nocturnal moths was hard. Even though the cover of deciduous dwarf shrubs and vegetation diversity could be correlated with the assemblage structure, it could not be correlated towards one specific habitat (Fig. 5) (Summerville et al. 2001; Root et al. 2017). Simply, since the assemblages of nocturnal moths were too

similar. That diversity of vegetation could be correlated with assembly structure should not be surprising, since moths are often linked to there host plant species, so when vegetation diversity increases so should moth diversity (Root et al. 2017). However, most moth species found in this study was using the boreal forests as habitats rather than the bogs themselves. Further, looking at species host-plant preference and habitat choice showing that many nocturnal moths caught were linked to tree species (especially deciduous trees). Indicating that tree diversity and understory tree count and stand basal area could be important for nocturnal moths in boreal environments. This would also follow findings from other habitats, e.g. temperate forests (Thomas 2002; Summerville and Crist 2004). For example, Schmidt and Roland (2006) showed that a loss of 50% or more of a stand resulted in a negative effect on nocturnal moth populations in forest environments. Novel habitats that are created could thus affect the nocturnal moths negatively and lead to larger novel areas having a negative effect on nocturnal moths since they lose understory trees and stand basal area.

The low number of caught moths makes me believe that nocturnal moths could work better as a group to use for studies in boreal forests or elsewhere rather than in bog environments. Also suggested by Lensu et al. (2011), who thought that the greatest effects by novel power line habitats might be visible in grasslands due to the fact pollinators, especially diurnal butterflies and wild bees, are generally more linked to open grasslands and work well as indicator species there (Berg et al. 2016; Russel et al. 2005). By also focusing on nocturnal moths when studying grasslands, we would get another group when analysing the changes in our landscapes, generating a more robust analyse for abundance and species diversity and the decline of pollinators (Solbrig 1991; Di Castri et al. 1992). However, nocturnal moths are not only constrained to grasslands but can also be found abundant in other types of environments. Nocturnal moths might thus yield new important information about how pollinator-flower ecosystem works in other habitats rather than just grasslands. This has also been suggested by Pohl et al. (2004), however, further studies are needed for nocturnal moths to work as a good indicator group on its own. They are a well-known taxonomically group of insects, but their general ecological needs are too poorly known (Pohl et al. 2004). There is thus a need for further studies focusing on nocturnal moths and their linkage to bog-, forest and grassland structures and vegetation structure. The species *Xestia baltica*, which was caught in our study, is linked to spruce forests with old grown structures and might give us a reference where to start studying nocturnal moths and how they can be used as an indicator group.

4.3 Implications and further studies

The low number of nocturnal moths caught during this study was surprising. Earlier studies have used similar equipment and been able to catch considerably more (Yela and Holyoak 1997; Summerville and Crist 2002; Mönkkönnen and Mutanen et al. 2003). However, why we caught such a low number of moths could have some possible explanations: First, the bog habitats might just be species or individual poor habitats for nocturnal moths and finding if novel habitats created by power lines in bog areas could therefore prove difficult. To generalize the results, the study should be repeated in other types of habitats such as different types of forests and meadows-grasslands to see how power lines effects on nocturnal moths there. By also further looking at different age of, and time since disturbance in, power line corridors and how it could impact the assembly structure could be of interest. The second explanation could be the time period chosen for sampling. The chosen time to collect moths was towards the end of the flying period, where the number of individuals decrease of natural reasons such as lower temperatures (Jonason et al. 2014). However, even if this is not wrong and been working for earlier studies (Várkonyi et al. 2003; Franzén and Johansson 2007), sampling for a longer duration of the year, preferable early May to late September, would results in a larger number of moths and more data to base any theories on. If studies cannot start earlier, it is important to start in early august and be out during the warm nights. This would probably result in a larger abundance of moths being caught. The last reason might be the collection methods and that it was not sufficient. Although, this seems unlikely since the traps usually yields large catches (EDC 1994; Yela and Holyoak 1997; Jonason et al. 2014). However, light trapping is dependent on cloudiness, where the number of individuals caught decrease with the fullness and how clear the moon is (Yela and Holyoak 1997; EDC 1994). In my study the cloudy nights often meant rainfall, which also affects the number of moths negatively. For the bait traps we chose to let them stand on the ground to not impact the reserves' environment with creating hanging structures. This might have been a mistake, since most research used traps suspended in trees (e.g. Pettersson and Franzén 2008). As well as not letting the wine ferment long enough after mixing the solution. By doing this and hanging the traps in trees could possibly have given a larger number of caught moths (Shuey 1997), consequently by the scent from the bait spreading over a larger area and attracting more moths.

If novel habitat creates areas which have a chance for colonization and the breeding structures necessary for lepidopteran species, they should work as habitats in a changing landscape (Summerville and Crist 2001; Lensu et al. 2011). The novel

habitats created by our power line cut through a conservation area of bog environments and the effects to both the vegetation and nocturnal moths were limited. Indicating that novel habitats in power lines might work as habitats, however, further studies investigating novel habitats effect on nocturnal moths could be important to fully understand if the effect really is limited. For the future research on nocturnal moths in novel habitats (for example power lines) there are some important aspects to consider. First, increasing the distance between the habitats to ensure both transects and traps are separated and have no chance to influence one another. This study could be called a small-scale case study, and to be able to confirm the results, the study should be repeated in larger scale with several areal repetitions and longer transects. Second, optimizing trap placement, by both placing them in optimal locations in the study site and also choosing the best habitat for studying nocturnal moths. Since, diurnal butterfly abundances are quite low within boreal forests and are more focused in grassland or open areas, nocturnal moths could be a group that have new useful information about vegetation structure, habitat quality and environmental health in boreal environments. They have been found to be useful in other ecosystems and could possibly be used as a new indicator group, however this still is to be proven in boreal forests.

5 Conclusions

No differences in the communities of nocturnal moths could be found between the novel habitats created by the power lines and the surrounding bog habitats. In the results there was a trend for power line habitats to being more dominant by swamp-mosses and including less vegetation structures, such as dwarf shrubs and small trees. This trend could have negative effects on nocturnal moths since many moths used deciduous trees and dwarf shrubs as host plants. My results also show the habitats being similar in assemblage structure, abundance, and species-diversity for nocturnal moths which might indicate that novel habitats created by this power line have a small effect on nocturnal moths. However, many of the species caught could be linked to the forests surrounding the bogs and not to the bogs themselves. This could indicate that bog environments are suboptimal places for investigating how nocturnal moths are affected by novel habitats, if these low numbers are not an anomaly. It would be important for further studies to generalize and strengthen the results. Future studies focusing on novel habitats and how they affect nocturnal moths should therefore be done not only in bogs but also in other habitats, where a greater effect might be found, for example in grassland or forest environments.

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Appendix
Species List

Tabell 3. *Species table over caught butterflies in both bait traps and light traps.*

Scientific name	Caught	Red list	Host plant	Habitat
Laothoe populi	1	LC	Populus and Salix species	Forests, parks and grassland
Catocala fraxini	3	LC	Deciduous trees (Alnus, Betula, Populus)	Deciduous forests and brushwoods
Autographa gamma	1	LC	Galium, Rubus, Trifolium, Urtica	Everywhere
Syngrapha interrogationis	1	LC	Betula, Calluna, Vaccinium	Mosses
Amphipyra pyramidea	1	LC*	Deciduous trees (Salix, Ulmus, Ligustrum, Betula, Populus)	Forests
Amphipyra perflua	10	LC	Populus tremula, Prunus, Lonicera, Ulmus	Deciduous forests and brushwoods
Celaena haworthii	7	LC	Grasses (Eriophorum, Juncus, Luzula)	Moist areas, from meadows to mosses
Conistra vaccinii	2	LC	Deciduous trees (Salix, Betula, Populus) and Vaccinium	Everywhere the host plants occur
Xylena solidaginis	6	LC	Salix, Betula, Calluna, Vaccinium	In Sweden often occurring in forest environments
Cosmia trapezina	1	LC	Deciduous trees (Salix, Prunus, Ulmus, Acer, Betula, Populus)	Forests, brushwoods, meadows and parks
Brachylomia viminalis	3	LC	Populus tremula and Salix species	In forest edges close to mosses, rivers and lakes
Antitype chi	1	LC	Rumex, Epilobium, Galium, Lactuca. Aquilegia vulgaris	Everywhere
Oligia latruncula	1	LC	Poaceae	Most open areas
Parastichtis suspecta	2	LC	Alnus, Betula, Populus, Salix	Many different habitat
Xestia baltica	3	NT	Betula nana, Vaccinium myrtillus	In coniferous forest often in old grown stands

Scientific name	Caught	Red list	Host plant	Habitat
Coenophila subrosea	3	LC	Andromeda polifolia, Betula nana, Calluna vulgaris, Myrica gale, Vaccinium uliginosum	Mosses
Eurois occulta	3	LC	Alnus incana, Betula sp., Calluna, Populus tremula, Vaccninum sp.	Forests and open land
Xestia c-nigrum	1	LC	Epilobium angustifolium, Stellaria media, Trifolium, Urtica	A bit everywhere, but mostly found in agricultural land
Euxoa nigricans	1	LC	Allium, Brassica, Polygonum, Polygonum aviculare	Many open areas
Diarsia dahlii	5	LC	Deciduous trees (Salix, Betula) and Vaccinium, Rubus	Often mosses and moist open areas
Noctuidae	3	N/A	N/A	N/A
Chloroclysta miata	1	LC	Betula, Salix, Vaccinium myrtillus	Forests
Crocallis elinguaria	1	LC	Deciduous trees and Vaccinium, Calluna, Rubus sp.	Everywhere
Epirrita sp.	3	N/A	Deciduous trees (Alnus, Salix, Betula)	Forests
Dysstroma truncata	2	LC	Alnus incana, Betula, Salix, Vaccinium	Forests
Dystroma citrata/truncata	1	N/A	Betula, Salix, Vaccinium	Forests
Eulithis populata	7	LC	Deciduous trees (Salix, Populus) and Vaccinium	Forests and meadows
Pennithera firmata	3	LC	Pinus sylvestris	Pine forests
Eulithis testata	1	LC	Betula, Salix, Vaccinium	Mires
Hydriomena furcata	2	LC	Calluna vulgaris, Salix caprea, Vaccinium	Everywhere
Geometridae	2	N/A	N/A	N/A

*New for the county of Västerbotten, Sweden.

Bald highlights either interesting finding of species due to protection value or due to habitat choice.

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